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SOVIET HIGH SPEED MACHINING OF CAST IRON WITH CERAMIC CUTTERS

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The high-cutting properties of tool materials are determined primarily by their red hardness, that is, the ability to retain their mechanical properties at high temperatures, and by a high resistance to abrasive wear. From this viewpoint, mineral materials, and in particular, ceramic materials, which possess a high red hardness, are very promising tool materials. Some of them retain their hardness at steel melting temperatures. Other qualities of these materials are as follows: they have less affinity with steel than metals. Other conditions being equal, this results in less nodule formation in the cutting process and higher quality of surface finish. Mineral materials are relatively inexpensive; their substitution for high-speed steel and hard alloys could effect substantial savings (to say nothing of savings in such metals as cobalt, tungsten, titanium, etc.).

In addition to the favorable qualities noted, mineral cutting materials also have intrinsic shortcomings, chief of which are a low resistance to rupture under normal stresses, little plasticity, and a low fatigue limit.

The problem of utilizing mineral materials in the manufacture of cutting tools was solved by Soviet scientists and engineers, who have been working in this field for a number of years.

In 1932, engineers at the Leningrad Plant imeni Lomonosov suggested the use of ceramic cutters for machining items made from porcelain, plastics, and nonferrous metals; in the period 1937 - 1940, the Tomsk Polytechnic Institute and the TsNIITMASh (Central Scientific Research Institute of Technology and Machine Building) conducted experiments in the machining of steel with mineral cutters; in 1948, research in this field was resumed by TsNIITMASh and was

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concluded in 1949 with the solution of a number of problems without which the practical application of mineral ceramics in the cutting of metals would not have been possible. This work included the search for a mineral material which would have sufficient [mechanical] strength, hardness, and resistance to wear at high temperatures; the establishment of optimum geometric parameters of the cutting portions of mineral cutters and the selection of cutting conditions; and the development of methods of fastening the blades of mineral material to a metal shank and of the technology of grinding and lapping (dovodka) tools fitted with mineral-ceramic blades

In the following years, as a result of the joint efforts of the MKhTI (Moscow Institute of Chemical Technology) imeni Mendeleyev and VNIIASh (All Union Scientific Research Institute of Abrasives and Grinding), the cutting properties of the new tool materials were improved considerably. The work was directed by I. I. Kitaygorodskiy, professor, and N. M. Pavlushin, docent, at MKhTI, and by S. G. Voronov, senior scientific associate, at the VNIIASh. VNII MSS (All Union Scientific Research Institute of the Ministry of Machine-Tool Building) developed new designs for ceramic tools and determined their cutting properties.

As shown by production tests, mineral-ceramic materials can be used successfully in place of hard alloys for finish and semifinish machining of steel and cast iron. At present, they are being used at many machine-building plants at significantly higher cutting speeds than hard-alloy tools. For example, G. Bortkevich, lathe operator and innovator, achieved a cutting speed of 1,400 meters per minute in the machining of cast iron; leaders in the Riga VEF Plant, 1,700 meters per minute; and P. Bykov, lathe operator and innovator, 1,845 meters per minute. [In an article written by Bykov published in <u>V Pomoshch' Profsoyuznomu Aktivu</u>, 22 November 1956, he claims to have achieved a cutting speed of 3,300 meters per minute in machining cast iron items with ceramic cutters.]

The results of research conducted on the use of cutters of mineral-ceramic materials in machining cast iron are given below. The work was done with cutters fitted with blades made of materials TsM-332 and TsV-13 which are two of the better types of ceramic cutting materials recommended at present for use in plants. For machining steel, material TsV-13 is not inferior in cutting qualities to hard alloys. Its semiindustrial production has been mastered by the VNIIASh. Material TsM-332, manufactured by the Moscow Hard Alloys Combine, excels material TsV-13 in cutting qualities

The cutting properties of ceramic materials were studied in machining various metals; however, the greatest effect was obtained in machining cast iron, which denotes the high resistance of ceramic materials to abrasive wear at high temperatures

Wear of the ceramic cutters in machining cast iron occurs along the front and back edges (perednaya i zadnaya gran'), the latter type of wear being predominant; therefore, optimum wear at the back edge was adopted as a criterion of dulling. Wear of the cutting edge, as a rule, occurs evenly along its entire working length

Figure 1, a graph, shows the wear of a cutter whose cutting part is of material TsM-332 in machining grey cast iron SCh 18-36. The speed of cutting was 300 meters per minute; the depth of the cut, 3 millimeters; and the feed, 0.3 millimeter per revolution.

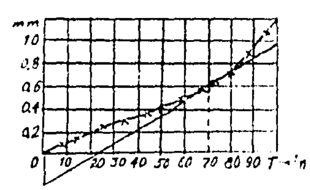

Figure 1

A large number of the graphs on wear obtained in experiments similar to the one above indicate that the optimum amount of wear of the back edge of ceramic cutters (corresponding to the maximum value of tool life) varies in machining cast iron between the limits of 0.6-0.9 millimeter.

The friction of the chip against the face of the cutter leads to the formation of a cup on it /cratering/; as a result of the wear of the front edge during operation, a certain amount of dropping of the cutting edge can be noticed. The effect of cutting speed on the life of ceramic cutters (with a depth of cut of one millimeter and a feed of 0.3 millimeter per revolution) is illustrated in Figure 2.

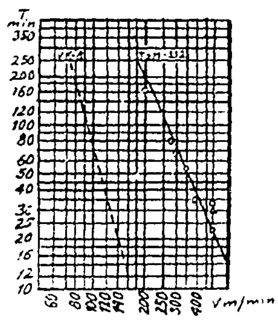

Figure 2

As can be seen from the graph, a 90-minute cutter life corresponds to a cutting speed of 275 meters per minute. On the same graph is plotted the value (Zavisimost') T=f(v) for the hard alloy VK-8, which was designed for machining cast iron.

A comparison of the curves shows that in using cutters whose cutting portion is of hard alloy VK-8, a 90-minute tool life corresponds to a cutting speed of 95 meters per minute, which is about one third the cutting speed of ceramic material. At a cutting speed of 150 meters per minute, the life of cutters whose cutting portion is of ceramic material is considerably longer (more than 20 times) than that of cutters of hard alloy VK-8.

The high degree of hardness and wear resistance of ceramic cutters and their capacity to withstand abrasive wear are creating the possibility of machining cast iron at high speeds, which would assure considerably greater output and a better surface quality than in machining with cutters whose cutting portion is of hard alloy or high-speed steel. At increased cutting speeds, the life of ceramic cutters in machining cast iron decreases at a slower rate than the life of hard-alloy cutters. For example, the cutting speed of cutters whose cutting portion is of material TsM-332 exceeds the cutting speed of cutters whose cutting portion is of hard alloy VK-8 2.7 times for a period of 180 minutes and 3.6 times for a period of 90 minutes.

As already pointed out, mineral materials, in contrast to hard alloys and high-speed steel, have a greater brittleness, that is, a very low plasticity and a relatively low fatigue limit. Therefore, it is important to ascertain the maximum feed and depth of cut permissible with ceramic materials to achieve normal operation of the cutters without premature chipping of the cutting edge. Experiments conducted with the aim of determining the effects of feed and depth of cut on the life and strength of ceramic cutters gave the following results.

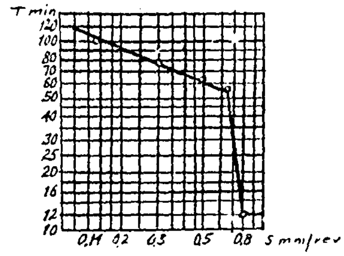

Figure 3

Figure 3 gives a graph of T=f(s), constructed for values of tool life corresponding to the optimum values of wear where v = 300 meters per minute, and t = one millimeter. (The types of cast iron and ceramic material are the same as in the previous experiments.)

With increases of feeds up to 0.65 millimeter per revolution, tool life decreases gradually. At ⩾0.65 millimeter per revolution, chipping of the cutting edge is observed, sharply decreasing its life. Figure 4 illustrates the effect of depth of cut on the life of ceramic cutters when v=300 meters per minute and s=0.3 millimeter per revolution.

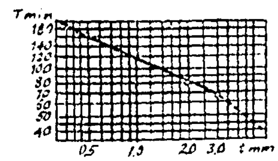

Figure 4

With an increase of t up to 3 millimeters, tool life decreases regularly. With further increase in the depth of cut, it decreases more rapidly, which is manifested by chipping of the cutting edge. As can be seen from a comparison of Figure 3 and Figure 4, the depth of cut and the feed have similar effects on the life of ceramic cutters.

Thus, the most advantageous application of existing ceramic materials is in finish and semifinish work.

Further studies were conducted to determine the maximum chip cross sections admissible by the [mechanical] strength of ceramic blades. They showed that in the machining of cast iron SCh 15-36 (after removal of the skin), blades of TsV-13 and TsM-332 can withstand a cutting depth of up to 10 millimeters per revolution.

Based on the results of the experiments, the following formula can be recommended for choosing the cutting conditions in machining cast iron with cutters fitted with the ceramic material TsM-332

$$v_{90} = \frac{217}{s^{0.2} t^{0.2}}$$

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The formula refers to the average cutting properties of ceramic material TsM-332; it is effective for machining gray cast iron of a hardness of H_B220-240 with a depth of cut up to 3 millimeters and feed up to 0.65 millimeter per revolution and with no impact load or vibration.

Along with the testing of cutting properties of ceramic materials, the technology of manufacturing ceramic cutters of various designs was developed and later perfected under plant conditions.

The blades are soldered to the shank with red copper, brass, or copper-zinc solder in oil or gas furnaces, as is done in the manufacture of hard-alloy cutters. The uniqueness lies in the slow heating and cooling of the blades. This rule must be strictly observed, since the low heat conductivity and high brittleness of ceramics are conducive to the formation of heat cracks. With the use of brass solder, it is recommended that the ceramic blades be heated in a furnace with slowly rising temperature to 900-1,000 degrees /centigrade/. The shanks are heated to approximately this same temperature. After soldering, the cutters are placed in a furnace which has been heated to a temperature of 700-800 degrees /centigrade/ and then cooled together with the furnace.

The blades can also be fastened to the shank by gluing (in cases where the cutters are intended for removing chips of small cross section). Silicate cement, glues BF-2 or BF-4, carbinol glue, etc., can be used.

Cutters with mechanically fastened blades can be of the most diverse designs, but they must all meet two basic requirements: the position of the blade in the recess of the shank must be adjusted so that the overhang of the blade does not exceed 0.5-0.7 millimeter; the blade should be fastened to the body of the holder in such a way that no concentrated reactive load will act on it.

Ceramic cutters are ground with wheels of green carborundum with a hardness of M3-CM1 and a grain of 46-80 at a slow wheel speed (peripheral speed of 2-5 meters per second). The application of a coolant is recommended.

Cutters with soldered blades should be ground in two stages: first the shank is ground on a corundum wheel, then the back edges of the blade are ground on a carborundum wheel. To avoid cracking and chipping of the blades, grinding should be done with a well-balanced, trued wheel, and excessive heating of the blade should not be permitted.

Blades that are to be mechanically fastened are ground separately in special holders. They are lapped (dovodka) on cast iron disks with a boron carbide powder of 180-230 grain. The speed of disk rotation is 1.5-2 meters per minute. After normal wear of the back edge (0.7 millimeter), it is recommended that ceramic cutters be lapped at once. The length of the operation, including grinding and lapping, does not exceed 3 minutes.

In the last 2 years, significant progress has been made in improving the cutting qualities of ceramic materials. There is every reason to expect that in the future, the cutting qualities of ceramic cutters will be still further increased through improvements in the technology and chemical composition of ceramic materials. It is evident also that by this means, it will be possible to achieve further increases in the /mechanical/ strength characteristics of ceramic materials, which, for the present, limit the application of ceramic tools to finish and semifinish operations. These problems should be solved through the future joint efforts of specialists in cutting and in the technology of ceramic materials.

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